Agric
I

MARCH, 1910 Chemical Series Vol. I, No. 9

Biological
& Medical
Serials

Memoirs of the Department of Agriculture in India

THE NATURE OF THE COLOUR OF BLACK COTTON SOIL

BY

H. E. ANNETT, B.SC. (LOND.), F.C.S., M.S.E.A.C

Officiating Imperial Agricultural Chemist

AGRICULTURAL RESEARCH INSTITUTE, PUSA

PUBLISHED FOR
THE IMPERIAL DEPARTMENT OF AGRICULTURE IN INDIA
BY
THACKER, SPINK & CO., CALCUTTA
W. THACKER & CO., 2, CREED LANE, LONDON

Price, Re. 1

STORAGE

MARCH, 1910 CHEMICAL SERIES VOL. I, NO. 9

MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA

THE NATURE OF THE COLOUR OF BLACK COTTON SOIL

BY

H. E. ANNETT, B.SC. (LOND.), F.C.S., M.S.E.A.C

Officiating Imperial Agricultural Chemist

AGRICULTURAL RESEARCH INSTITUTE, PUSA

PUBLISHED FOR

THE IMPERIAL DEPARTMENT OF AGRICULTURE IN INDIA

BY

THACKER, SPINK & CO., CALCUTTA

W. THACKER & CO., 2, CREED LANE, LONDON

CALCUTTA:

PRINTED BY THACKER, SPINK AND CO.

PREFACE.

I would like to express my thanks to B. P. Standen, Esq., and G. F. Keatinge, Esq., Directors of Agriculture in the Central Provinces and Bombay, respectively, for having kindly arranged tours for me. Also to Messrs. D. Clouston, G. Evans, T. F. Main, W. Roberts, R. W. Wood, and others who have so kindly provided me with samples of soil for this investigation.

Dr. Leather has helped me with his wide knowledge of Indian soils, and I have also to thank the Assistants to the Imperial Agricultural Chemist for the help rendered in carrying out various analyses.

H. E. A.

Pusa,
September, 1909.

Digitized by the Internet Archive
in 2008 with funding from
Microsoft Corporation

http://www.archive.org/details/n9memoirschemica01impeuoft

THE NATURE OF THE COLOUR OF BLACK COTTON SOIL.

BY

H. E. ANNETT, B.Sc. (Lond.), F.C.S., M.S.E.A.C.,

Offg. Imperial Agricultural Chemist.

Introduction.

The black cotton soil of India covers an area of at least 200,000 sq. miles and ranks as the second most important of our Indian soils. On it by far the largest proportion of our Indian cotton crop is grown.

The origin of the soil and the cause of its dark colour have long been matters of discussion.

As far back as 1829 this soil was described by Christie.* From that date there has been a succession of papers dealing with it; the principal writers having been Newbold,† Hislop,‡ W. T. Blanford,§ Oldham,¶ and Leather.‖ These, however, dealt more with the origin of the soil than with the cause of its colour and most of the writers assumed the colour must be due to organic matter. Other theories have been advanced and will be enumerated further on in this paper.

Some years ago Captain A. Aytoun, R.A., published an interesting pamphlet on the "Origin and distribution of the Black Cotton Soils of the Indian Peninsula." He suggests that the black colour is due to organic matter, and that the black soil is

---

* *Edin. Phil. Jour.*, VI, 119 (1829); VII, 50 (1829).

† Proc. Roy. Soc., IV, 54 (1838).

‡ *Jour. Bo. Br. Roy. As. Soc.*, V, 61 (1853).

§ Memoirs, Geol. Survey, VI, 235 (1869); Records, VIII, 50 (1875).

¶ Records, Geol. Survey, IV, 80 (1871).

‖ *Agric. Ledger*, 1898, No. 2, Soils.

formed in depressions where marsh-loving plants grow up and die. He thinks that it is probable that the cotton plant has degenerated in India and that this degeneration is due to the gradual exhaustion of the soil.

Dr. Leather took up the question about twelve years ago, and made an investigation into the cause of the colour, though he did not quite settle the question. He was never able to finish his investigations, but he came to the conclusion that the colour of the soil was not due to organic matter but to the presence of some black mineral.

Besides the colour of the soil, another point which seemed to need investigation is the wonderful power the soil has of cracking during dry weather. The rents thus formed are constant sources of danger to the horseman riding through the black soil country. In some of the previous writings on the subject, the idea seemed to prevail that the substance causing the black colour was also the constituent which imparted this cracking power to the soil.

One hears tales of the wonderful fertility of certain tracts of this country, and therefore one would expect to see a fairly thick growth of natural vegetation. But a more disappointing outlook than is to be observed at those times when there are no crops on the ground, it is hard to imagine. Bare flat-topped hills of trap rock are typical of the black soil country and always give the traveller notice that he is approaching this type of soil.

The only tree which seems to grow on the soil is the Babul (*Acacia arabica*). Other trees there are practically none. It has been suggested that the roots of no other tree can endure the cracking which goes on in the soil in the dry weather.

The crops grown on the soil are very varied. The main one is cotton. We also get juar, bajri, sugar-cane, wheat, gram, linseed, tur.

The colour of the soil is in many cases a very deep black, but it varies between this and a slaty grey colour. The depth of colour depends on how the soil has been treated or whether rain

has recently fallen on it or no. Wet land freshly stirred generally appears the blackest of all.

The varieties of black cotton soil are numerous. Typically it is a deep black soil. As we approach the hills, it thins out to a lighter colour, and becomes mixed with fragments of rocks. It is very noticeable that black soils occupy the valleys, and as the hills are approached, the colour changes to red.

At Surat, the soil appears to have been all alluvial in its formation. It contains no pebbles of any kind, even Kankar* is rare, and it does not vary in colour throughout its whole depth. In the south of the Bombay Presidency around Dharwar, Hubli, etc., the soil contains numerous small pieces of Kankar.

The nature of the colour of black cotton soil therefore seemed to call for investigation, and Dr. Leather suggested to me that I should take the matter up since owing to pressure of other matters he was unable to do so himself.

Some of the theories which have been advanced at various times as to the cause of the black colour are rather quaint. It was once suggested to Dr. Leather† that the colour was due to the presence of a plant which exuded a black dye from its roots.

The presence of organic salts of iron is also suggested in a D. O. letter from Mr. Oldham to Dr. Leather.‡

As pointed out by Leather, this view cannot be entertained, owing to the great rate of oxidation in these soils at the high temperature.

Oldham§ and Medlicott|| and Blanford state that "the essential character of a dark colour appears to be due in all cases to the admixture of organic matter, and perhaps the presence of a small quantity of iron." These statements seem based on analyses by Tween. Leather points out that these analyses

---

* Pieces of carbonate of lime.

† *Agricultural Ledger*, 1898, No. 2, Soils.

‡ *Agricultural Ledger*, 1898, No. 2, Soils, by J. W. Leather.

§ Geology of India, 2nd edition, Oldham, p. 14.

|| Geology of India, Part I, Medlicott & Blanford, pp. 433-4.

must have been carried out by igniting the soil, and hence the organic matter found includes combined water.

Leather came to the conclusion that the colour is *not* due to organic matter, but that it is due to the presence of some black mineral and that this might be graphite fused on to silicates. He also made analyses of large numbers of these soils. The reasons put forward by Leather to shew that the colour is not due to organic matter are the following :—

(1) The proportion of total nitrogen is as low as in most other soils which lose only $\frac{1}{2}$ or $\frac{1}{3}$ as much in weight when heated ; this indicates a low proportion of organic matter.

(2) Although the loss on igniting the soils is almost uniformly high, it is suggested that the greater part of this loss is due to expulsion of combined water, because the manner in which these regur soils contract on drying, indicates a high proportion of hydrated ferric oxide or alumina and either of these compounds would lose the water of hydration on being heated.

(3) After boiling these soils with strong sulphuric acid to destroy all organic matter, the siliceous residue is still black.

Experimental.

Presence of a Black Mineral.—On shaking up a sample of black cotton soil in a basin, I observed an appreciable amount of a black substance at the bottom of the vessel. All my samples of black soil were therefore tested for the presence of this substance. The samples were ground very fine, and then treated with very weak hydrochloric acid until no more effervescence took place. Each sample was then shaken up in a porcelain basin. By a process of "cradling," the muddy liquid was thrown off and more water was added, and the "cradling" process repeated. From each of the black soils a residue was in this way obtained, which was seen to be very rich in these black particles. Specimens of many Indian soils, other than black soils, were treated in the same way, but no such black substance was obtained. The soils so treated were from Shillong, various soils from the Gangetic

alluvium, Bangalore, etc. Black soils from Surat, Broach, Poona and Bhusawal (Bombay Presidency), Nagpur, Akola, Betul (C. P.) and Samalkot (Madras) all gave a fair amount of the black substance.

On examining this black mineral, it was found to be strongly attracted by a magnet, and to be very rich in iron. The soil particles were next tested with a magnet, and the particles of all black cotton soils so far examined have been found to be magnetic. The particles of other soils were tested in a similar way. Such red soils as those of Shillong and Bangalore which contain much ferric oxide were also magnetic to a small extent, but to nothing like the same extent as the black cotton soils.

Hence it appears that these soils contain a black substance which is peculiar to them.

Prof. Hilgard, in a recent letter to Dr. Leather, detailing the results of his examination of two black cotton soils, reports that the "microscopic examination of portions of both soils proves the presence of a certain amount of magnetite, and also of some rather indefinite black particles which I take to be partly decomposed hornblende or augite, probably derived from underlying rock just as is the case in the soils resulting from the decomposition of our basalt soils, but the latter yield rather light soils, poor in humus and of reddish tint and nowhere anything like your Indian regur."

Amount of Black Mineral Present.—The presence of a black mineral having been established, it next remained to determine in what quantity it occurs, and also whether this quantity is sufficient to account for the black colour.

The most obvious method for determining the amount present seemed to be by the use of the magnet. However, although an electro-magnet was fitted up, it was not found possible to separate the black mineral satisfactorily by its means even when the soil was ground up with water and the magnet poles immersed in the liquid. Practically every soil particle is magnetic and is attracted to the magnet with the black substance.

After many attempts the following method was adhered to in order to estimate quantitatively the amount of black susbtance present.

25 grms. of the soil were finely ground in an agate mortar. It was then treated with 3 per cent. hydrochloric acid in a large porcelain dish until all calcium carbonate had been dissolved. The dish was then given a rotary movement in the hand. Thus the soil particles were set in motion and the heavy particles of the black mineral settled to the bottom. The muddy liquid was then decanted into a big beaker. More water was added to the basin, which was again rotated as above. The process was repeated many times and at last the residue in the basin consisted of the practically pure black mineral. This was collected. The soil which had been poured into the beaker was again cradled. This was placed with the first lot obtained. The process was repeated until the soil yielded no more black mineral in this way.

The amount of black mineral obtained in this manner from various soils is here set out :—

	Per cent. of black mineral by weight.
Surat soil (1)	2·5
Ditto (2)	1·8
Ditto (3)	1·5
Ditto (4)	1·6
Ditto (5)	1·8
Chikoli, Berar (1)	1·5
Ditto (2)	3·0
Yeotmal, Berar	1·8
Akola, No. 1	1·3
Samalkot, Madras	0·3

It must be remembered that all the black substances have not been removed from the soil by this method. The particles of soil left behind were still magnetic. Only the black substance which is loose in the soil has been thus separated.

It is next desirable to know how much black substance is necessary in order to give a black appearance to the soil. Various amounts of magnetite were added to equal weights of Pusa soil which is very light coloured. When 10 per cent. of the black substance was present, then the soil was very dark.

5 per cent. was found to darken it considerably and even 2—3 per cent. had a great effect. From my experiments I concluded that with a soil which is already a little dark the addition of 3—4 per cent. of magnetite would cause a very appreciable darkening, but not enough to account for the very deep black colour of some of these soils.

It next seemed desirable to try and devise a chemical method for the estimation of the amount of black substance present. After many attempts, however, it was found impossible to do this.

On boiling the soil with strong sulphuric acid as in the Kjeldahl process, the residue obtained in the case of all black cotton soils is more or less black, whereas the residue from all other soils is either white or white and red. This fact was observed by Leather (*Agricl. Ledger*, No. 2, 1898, p. 20).

This residue was still found to be magnetic on washing and drying. On boiling these black residues with hydrochloric acid for some hours, however, and washing and drying, they were found to be no longer magnetic. On again boiling the residues in sulphuric acid, a pure white residue was now obtained which was non-magnetic.

It occurred to me therefore to estimate the amount of black substance present in a soil by first boiling it with sulphuric acid and then estimating the amount of iron which goes into solution by boiling the residue with hydrochloric acid. However, the results obtained by this method were no better than those obtained by mechanical separation owing to the fact that the pure black substance was found to be soluble to a large but variable extent in sulphuric acid.

A few of the results thus obtained may, however, be here quoted : 20 grams each of Pusa and Surat soils and of two soils from Akola farm (Central Provinces), were boiled with sulphuric acid as in the Kjeldahl process but without addition of potassium sulphate. Also an extra lot of 20 grams of Pusa soil to which 5 per cent. of magnetite had been added was similarly boiled. The boiling was continued until all carbon was destroyed. The residues in each case were then collected and washed free from acid. The

residue from Pusa soil without magnetite appeared white. The residues from the three black soils (Surat and Akola) contained many black particles, but there was *no* red oxide of iron visible. The residue from the Pusa soil to which magnetite had been added was seen to contain a good deal of black substance. The iron was now determined in each residue by boiling it for 8 hours with hydrochloric acid on a sand bath, filtering and estimating the iron in the solution with potassium dichromate.

The following table shews the results :—

Soil.	Iron found calculated as magnetite Fe_3O_4.
	per cent.
Pusa (without magnetite)	·04
„ (with 5% ditto)	2·20
Surat soil	1·00
Akola soil No. 1	2·06
Ditto „ 2	2·25

The solubility of the black substance has been found to be somewhere about 55 per cent. in strong sulphuric acid. About 3/5 of the magnetite added to the Pusa soil has been dissolved, so if all the iron is present as magnetite the Surat soil appears to contain 2—3 per cent. and the Akola soils 4—5 per cent. of magnetite.

These figures are naturally very approximate, but they are given as being perhaps some indication of the amount of black substance present in these soils.

An attempt was made to separate the black substance by the use of Thoulet's* solution. This was obtained of a sp. gr. 3·1, but the results with it were not satisfactory. The figures obtained tallied roughly with those obtained by the method of mechanical separation, as was to be expected.

Analysis of Black Substance.—A qualitative analysis shewed the mineral to be mainly magnetite, containing fair quantities of titanium and small amounts of magnesium.

Purification was carried out by grinding with water in an agate mortar and then extracting with a magnet. The substance

* *Wiley's Agric. Analysis, Soils*, Vol. 1, p. 297 (1906).

extracted was again ground and extracted. This process was repeated until microscopic examination shewed the substance to consist of the pure black mineral.

Quantitative analyses of the black substance from various soils were then carried out and are here quoted :—

	Surat Soil.		
	Sample I.	Sample II.	Yeotmal, Berar.
Iron as $Fe_3 O_4$	77·40	68·73	70·90
Titanium as $Ti O_2$	19·09	14·67	21·75
Magnesium as Mg O	3·51	16·60	7·35
Total ...	100·00	100·00	100·00

The iron, titanium and magnesium were determined, and after satisfying myself that the remainder was earthy matter, I assumed in the calculations that the substance consisted of $Fe_3 O_4$, $Ti O_2$ and Mg O. This was done as it was found impossible to get the substance *entirely* free from earthy matter. One analysis, however, may be quoted to shew to what extent of purity I was able to bring the samples.

Surat Soil I.

$Fe_3 O_4$	73·24
$Ti O_2$	18·07
Mg O	3·32
	94·63

Method of analysis.—The *iron* was determined in the hydrochloric acid solution with titanous chloride.*

Titanium was estimated in the hydrochloric acid solution after reduction with zinc by titration with methylene blue.† This method, after a little practice, was found to give excellent results. On boiling the black substance with hydrochloric acid an insoluble residue was left which contained much of the titanium. This was fused with caustic potash and then dissolved in hydrochloric acid. The titanium was then estimated in this solution by reduction with zinc and titration with methylene blue as before.

* *Sutton's* volumetric analysis.

† *J. S. C. I.*, Feby 27th, 1909, Eva Hibbert.

Magnesium was determined as pyrophosphate.

The proportion of ferrous to ferric iron was determined in a sample of the black substance obtained from Surat soil. The result obtained was, total iron found 53·01 per cent. ; ferrous iron found 16·74 per cent. ; ferrous iron for Fe_3O_4 theory 17·67. Assuming the iron is present as magnetic oxide, this result is quite satisfactory. In any case a lower result than the theory for ferrous iron would be expected since the magnesium present probably has displaced some of the ferrous iron.

The method used for determining the ferrous iron consisted in dissolving the substance in hydrochloric acid in an atmosphere of carbon dioxide and then to titrate with potassium permanganate after adding manganous sulphate.*

Properties of the black substances.—The substance when isolated is in the form of lustrous black crystals.

Its sp. gr. is about 5·7. It is only partially soluble in boiling sulphuric acid. After boiling for three hours about 55 per cent. went into solution. This explains why black residues are obtained on boiling these soils with sulphuric acid. It is no more soluble in nitric acid.

It is readily soluble in boiling hydrochloric acid, though a small residue of titanic oxide is left behind.

It is attracted by a magnet though much less readily than pure magnetite ; in fact, some particles of it are only with great difficulty picked up with a magnet.

Occurrence of Black Sands in America.—In certain of the Western States of America black sands occur associated with the soils. These sands chiefly occur in Oregon and California, and O. H. Hershey† makes reference to their occurrence on the Isthmus of Panama.

Many investigations have been made into the composition of these sands. The magnetite occurring in them usually contains from five to ten per cent. of titanium and constitutes a greater

* *Chem. News*, 99, 61, 73

† A remarkable deposit of black iron sand, Isthmus of Panama. O. H. Hershey, Min. and Sci. Press, Oct. 22, 1898.

supply of useful iron than any other available source known on the Pacific coast.*

Associated with these black sands in America, however, are appreciable quantities of gold and platinum, especially of the former.

So far I have been unable to find gold in the black substance I have isolated from the soils, but I have only been able to obtain small quantities of it at present.

Along the banks of most of the rivers in the Deccan and also of the Tapti at Surat may be seen quantities of a deep black sand washed up by the river. These rivers all flow through trap rock districts and black soil, and thus we have another indication of the presence of appreciable quantities of this black substance in the soils. I collected several samples of this black sand from the Tapti at Surat, from the Tapti at Bhusawal (Bombay Presidency) and several other places. The following is an analysis of a sample collected at Bhusawal.

$Fe = Fe_3 O_4$	75·09
$Ti = Ti O_2$	14·33
$Mg = Mg O$	9·16
$Ca = Ca O$	1·42
	100·00

After heavy showers of rain in the black soil country I have often noticed a deposit of black sand in the little gullies scoured out in the roadside by the rain.

Oldham† says "many of the dolorites of the Deccan contain iron in the form of magnetite and large quantities of magnetic iron sand are found in the beds of streams which flow over the trap, whilst bands both of magnetite and hæmatite are locally common in the metamorphic rocks." On p. 380 Oldham goes on to say: "It has been stated that magnetite occurs in many of the Deccan basalts, but until far more analyses have been made, it is impossible to say whether any of the rocks contain as large

* Black Sands of the Pacific Slope in 1905, D. T. Day and R. H. Richards, Dept. of the Interior, U. S. Geol. Survey.

† Geology of India, p. 379.

a proportion of iron as the laterite. It is probable that some may, but 15—20 per cent. in any basalt is exceptional."

Amount of Organic Matter present in the Soil.— As mentioned on a previous page, various writers have considered the black colour to be primarily due to the presence of organic matter. I have also set out the chief reasons put forward by Leather to shew that this explanation of the colour cannot be entertained. In addition to this, black cotton soil has been generally considered of late years by officers of the Agricultural Department to be deficient in organic matter. Thus Clouston in a paper on Manuring of Cotton* in the Central Provinces mentions that it is a well-known fact that black cotton soils are deficient in humus, and also he says the cracks help to aerate the soil and thus humus would have more chance of being oxidised. He advocates the use of organic manure and says that nitrogenous manures are found to have a great effect.

Also at certain hilly districts in Bombay, *e.g.*, at Lonavla, it has been found that cake manures and artificial nitrogenous manures have a wonderful effect on plant growth, indicating the soil to be poor in organic matter.

However, Oldham† notes that Leather did not determine organic carbon in these soils and says this would seem to be an important point.

Hilgard‡ also says : " Leather attributes the black colour of the regur to some mineral substance rather than to humus, but his arguments are not quite convincing so long as the Grandeau test has not been made."

It therefore seemed advisable to determine both the organic carbon and the soluble humus in these soils.

Owing to the absence of gas, etc., the earlier determinations of organic carbon were done by the wet combustion or chromic acid method.

---

* *Agricultural Journal of India*, Vol. II, Part II.

† See letter in *Agricultural Ledger* (Leather), 1898, No. 2, p. 24.

‡ *Soils*, Hilgard, p. 415.

Later, however, since the completion of the Agricultural Research Institute, determinations have been carried out by the dry combustion method with copper oxide in a current of oxygen. The latter method, however, besides involving the determination of the amount of carbonate present in the soil, also involved a determination of the alkali carbonates left behind after the combustion, in the soil residue. Had the amount of these latter not been determined, a considerable error would have resulted.

The figures obtained are expressed as percentage of organic carbon in the soil, it not being considered desirable to express this as organic matter by multiplying by any factor.

In the cases where the carbon was determined in the same soil by both methods, the figures are given for the purpose of putting on record the difference to be expected in the results obtained. The amount of organic carbon found in various other Indian soils is also set out.

		Per cent. organic carbon.	
	Soil taken.	Wet combustion method.	Dry combustion method.
	(1) Akola soil ...	...	·83
	(2) 1st class black cotton soil	·94	1·10
	(3) 2nd „ ...	...	1·00
	Surat soil	·49	·70
	Samalkot soil (Madras) ...	...	1·16
	Akola survey No. 58 ...	·68	...
Not black cotton soil	6 miles north of Sukhtawa (sandstone)	...	0·82
	Pusa	0·46	...
	Shillong	...	2·63
	Bangalore	...	0 46
	Sandy soil, Woburn, England, barley after wheat ...	...	1·19
	* Pasture (Rothamsted) 0″—9″ ...	...	3·60
	* Broadbalk „ 0″—9″ ...	...	1·57
	* Geescroft „ 0″—9″ ...	...	1·13

The chromic acid method therefore gives lower results than those obtained by combustion in Oxygen. This was also found to be the case by Warington and Peake,† and by Cameron

* *J. C. S.*, 1906 (89) 595, Hall, Miller & Marmu.

† Trans. C. S., 1880, 37, 617.

and Brazeale.* Hall, Miller and Marmu† shewed that by the addition of a short tube containing red hot copper oxide to complete the combustion the whole of the carbon in the soil can be obtained as carbon dioxide.

The amount of organic carbon in these typical black cotton soils is therefore not unusually high. So that from these figures one could hardly say that the black colour is due to the presence of organic matter.

Soluble Humus.—This was estimated by the method recommended by the U. S. Department of Agriculture.‡

10 gms. of the soil were washed in a Buchner funnel with 1 per cent. hydrochloric acid till the filtrate was free from lime. The soil was then washed with water until the washings were no longer acid. It was then transferred to a stoppered cylinder together with 500 c.c. of 4 per cent. ammonia and allowed to remain with occasional shaking for 24 hours. After standing a further 12 hours an aliquot portion of the liquid was filtered off through asbestos and evaporated to dryness in a platinum basin. The dried residue was weighed and then ignited. Another weight was then taken. The loss of weight is equal to the soluble humus.

	Soil.	Soluble humus per cent.
	Akola No. 1	1·33
	Yeotmal, Berar	1·86
	Surat	0·91
	Samalkot	1·50
	Akola No. 2	1·25
	Akola (Hilgard)	0·70
	Nagpur (Hilgard)	0·90
Not black cotton soil	Shillong	2·49
Not black cotton soil	Pusa soil (sandy)	0·69
Not black cotton soil	„ (clay)	0·89

From the amounts of soluble humus and organic carbon found we cannot say that black cotton soils are rich in organic matter. If we compare the amount of organic carbon in these

* *Jour. Amer. C. S.*, 1903, 26, 29.

† *J. C. S.*, 1906, 89, p. 595, Hall, Miller and Marmu.

‡ Official and Provisional Methods of Analysis, Association of Official Agricultural Chemists, 1908.

soils, however, with the amount of soluble humus, a very interesting fact is observable. The total organic matter in a soil is often calculated from the amount of organic carbon found by multiplying the amount of this by a factor. Thus Hall * states that the organic matter in the soil is sometimes assumed to contain 55 per cent. of carbon. We can therefore roughly assume the organic matter in the soil to contain about half its weight of carbon.

On looking at the analyses of black soils we find that Samalkot soil contains 1·16 per cent. of organic carbon and therefore should contain about 2 per cent. of total organic matter. The soluble humus in it, however, is 1·50 ; *i.e.*, most of the organic matter is in the form of soluble humus. The same is the case with the other black soils examined. But with other soils, such as Shillong soil, we find the organic matter is well over 5 per cent., though the soluble humus only amounts to 2·49 per cent. The same thing is noticeable with Pusa soil. Thus in black cotton soils the organic matter appears to be largely present as soluble humus.

Although it appears improbable that so small an amount as 1—2 per cent. of humus could have an appreciable effect on the colour of the soil, it was thought desirable to test this point. Accordingly various black soils were treated with hydrochloric acid to decompose the "humates" and then washed free of acid.

Each soil thus treated was now divided into two equal portions, one of which was then shaken with 4 per cent. ammonia solution and allowed to settle. The soluble humus was thus extracted and the colour of the soil remaining was compared with that of the portion of soil which had not been treated with ammonia. In every black soil examined the portion extracted with ammonia was distinctly lighter in colour than the other portion. A light-coloured Pusa soil containing only 0·69 per cent. soluble humus shewed no such difference in colour after ammonia treatment, whereas a Shillong soil containing 2·49 per cent. soluble humus

* *The Soil*, 1908 edition, p. 143.

became much lighter in colour after ammonia extraction. The black soils examined were from Surat, Samalkot, and three from the Central Provinces.

These experiments prove that although the amount of humus is not very high in these soils, yet the dark colour is partly due to its presence.

The Cracking of the Soil.—As mentioned already, this soil is noted for the large cracks which form in it during dry weather. Some observers have supposed this property to depend in some way on the presence of the black substance which causes the colour.

It seemed, however, far more likely that it was due to the presence of a large proportion of clay. Accordingly the amount of clay was determined in a number of soils. The amounts found are set out in the table.

	Without preliminary acid treatment.	With preliminary acid treatment.
Akola 1st class B. C. soil ...	... ...	59·50
Akola black cotton mixed with red	...	31·18
Surat	.....	42·15
Samalkot, Madras	.....	59·09
Akola survey No. 51	16·83	26·04
„ 12	26·61	48·25
„ 58	19·19	23·30
Amrai Farm field, Berar ...	15·90	35·74
Hagari Farm, Bellary ...	16·39	30·78

The method for the clay determination was the sedimentation method described by Hall.* In the second column the sample of soil was first treated with N/5 hydrochloric acid† to dissolve carbonate. In the first column some figures are given which were obtained after simply boiling the sample for half an hour in water instead of the preliminary acid treatment.

As will be seen, the acid treatment shews a much higher proportion of "clay."‡ It was thought worth while to put both sets of determinations on record here.

* *The Soil*, 1908, p. 51.

† *Schloesing, Compt. rend.*, 1874, 78, p. 1276.

‡ See also *Hall. Jour. Chem. Soc.*, 1904, Vol. 85, p. 960

The separated "clay" apparently consisted of much finer particles than usually occurs in soils.

It is therefore quite obvious that the high proportion of clay would in itself account for the "cracking" in these soils.

A practical point here however arises. These soils, though mostly heavy clay soils, behave rather differently from heavy clays such as are known in England. These latter require very careful treatment after rain, and if ploughed when too wet turn up into large unbreakable clods which are only with great difficulty broken down when they dry. On the other hand, black soil can be kneaded up with water to form a very plastic mass, but when this dries, it can readily be broken to a powder. Wet clods of the earth in the field can readily be broken to a powder by gentle pressure. It occurred to me that the explanation of this might be found in the presence of the black mineral. Laboratory experiments on this point, however, did not lead to any very definite conclusion.

Chemical Composition of the Soil.—The composition of the soil does not vary within wide limits. The analyses given are typical ones.

	Nagpur Farm.	Akola.	Average of 18 soils.
Insoluble silicates and sand	68·71	56·11	68·41
Peroxide of iron ($Fe_2 O_3$)	11·25	9·83	7·13
Alumina ($Al_2 O_3$)	9·39	10·68	10·14
Manganese oxide (Mn O)	·26	.....	·17
Lime (Ca O)	1·82	6·59	2·90
Magnesia (Mg O)	1·79	2·51	2·27
Potash (K_2 O) and Soda (Na_2 O)	·45	0·37 and 0·23	·41
Phosphoric acid ($P_2 O_5$)	·06	0·08	·06
Sulphuric acid (SO_3)	nil	——	——
Carbonic acid (CO_2)	·44	4·18	1·62
Organic matter and combined water	5·83	9·42	6·58
Total Nitrogen	·05	·03	·03

All the above analyses except that of Akola soil were published by Leather,* though the average of 18 soils was actually

* *Agricultural Ledger*, No. 2, 1898.

taken from Hilgard* who averaged Leather's figures in his own book.

In these analyses both the amounts of iron and of alumina are high. The latter indicates a large amount of clay, which has been found.

Numerous iron determinations have been made in these black soils.

The analyses by Leather shewed an iron content varying between 6 and 14 per cent. of $Fe_2 O_3$.

My own analyses have all shewn a similarly high iron content.

		Per cent. $Fe_2 O_3$
Hagari Farm, Bellary, Madras	...	11·08
Yeotmal, Berar	...	11·53
Akola, No. 1	...	14·36
Surat soil	...	11·29
Samalkot	...	11·25

Origin of black soil.—The origin of black soil has long been a matter of discussion, but it seems to be fairly clear now that it is formed from the trap rock. But this is a question I do not propose to enter into here. A point which this paper does throw light on, however, is that the alluvial black soils such as those of Surat are similar to the sedentary black soils of the Deccan. These alluvial black soils are well seen at Surat (Bombay Presidency) and at Samalkot (Madras Presidency). Surat is at the mouth of the river Tapti and Samalkot at the mouth of the Godaveri and both these rivers flow through the trap districts for most of their course.

Reference may here be made, however, to an examination of some decomposing amygdaloid trap rock underlying black soil found at Bhusawal, Bombay Presidency. A sample of this was finely ground in an agate mortar under water. The fine powder was then cradled to separate any black substance as described on p. 188. The amount of black substance separated amounted to just under 5 per cent. of the rock.

* *Soils, Hilgard*, p. 412.

An analysis of this black substance gave the following figures :—

Iron	$= Fe_3 O_4$	84·23
Titanium	$= Ti O_2$	12·18

The black soil appeared to have been formed *in situ* from this "murum," and the above figures are interesting as indicating that a similar black substance appears to occur both in the decomposing trap rock and in the soil itself.

Conclusions.—1. The black colour of these soils is mainly due to the presence of several per cent. of titaniferous magnetite and of 1—2 per cent. of soluble humus. The mineral substance alone would not account for the deep black colour. Here it may be noted that the black colour of certain Hawaiian soils is in part attributed to mineral matter, in this case manganese dioxide.*

2. The soils are not rich in organic matter judged from the European standard, and organic nitrogenous manures appear to give good results on them.

3. The amount of clay is exceptionally high and this accounts for the "cracking" which takes place in these soils during the hot dry weather.

---

* *J. Ind. & Eng. Chem.*, August 1909.

PUBLICATIONS OF THE IMPERIAL DEPARTMENT OF AGRICULTURE IN INDIA.

[TO BE HAD FROM MESSRS. THACKER, SPINK & CO. CALCUTTA.]

Annual Report of the Imperial Department of Agriculture in India for the year 1904-05 Price, As. 12 or 1*s.* 2*d.*

Report of the Imperial Department of Agriculture in India for the years 1905-06 and 1906-07. Price, As. 6 or 7*d.*

Proceedings of the Board of Agriculture in India, held at Pusa on the 6th January 1905 and following days (with Appendices).

Proceedings of the Board of Agriculture in India, held at Pusa on the 15th January 1906 and following days (with Appendices). Price, As. 12 or 1*s.* 2*d.*

Proceedings of the Board of Agriculture in India, held at Cawnpur on the 18th February 1907 and following days (with Appendices). Price, Re. 1-2 or 1*s.* 6*d.*

Proceedings of the Board of Agriculture in India, held at Pusa on the 17th February 1908 and following days (with Appendices). Price, As. 8 or 9*d.*

Proceedings of the Board of Agriculture in India, held at Nagpur on the 15th February 1909 and following days (with Appendices). Price, As. 8 or 9*d.*

Standard Curriculum for Provincial Agricultural Colleges as recommended by the Board of Agriculture, 1908. Price, As. 4 or 5*d.*

The "*Agricultural Journal of India.*" A Quarterly Journal dealing with subjects connected with field and garden crops, economic plants and fruits, soils, manures, methods of cultivation, irrigation, climatic conditions, insect pest, fungus diseases, co-operative credit, agricultural cattle, farm implements and other agricultural matters in India. Illustrations, including coloured plates, form a prominent feature of the Journal. It is edited by the Inspector-General of Agriculture in India assisted by an Advisory Committee of the staff of the Agricultural Research Institute, Pusa. *Annual Subscription*, Rs. 6 or 8*s.*; Single copy, Rs. 2.

Memoirs of the Department of Agriculture in India are issued from time to time as matter is available, in separate series, such as Chemistry, Botany, Entomology and the like.

BOTANICAL SERIES.

Vol. I, No. I. The Haustorium of the Santalum Album—Early Stages by C. A. BARBER, M.A., F.L.S. Price, Re. 1.

Part II.—The Structure of the Mature Haustorium and Inter-relations between Host and Parasite by C. A. BARBER, M.A., F.L.S. Price, Rs. 3.

Vol. I, No. II. Indian Wheat Rusts by E. J. BUTLER, M.B., F.L.S.; and J. M. HAYMAN. Price, Rs. 3.

Vol. I, No. III. Fungus Diseases of Sugarcane in Bengal by E. J. BUTLER, M.B., F.L.S. Price, Rs. 3.

Vol. I, No. IV. Gossypium obtusifolium, Roxburgh, by I. H. BURKILL, M.A. Price, Re. 1.

Vol. I, No. V. An Account of the Genus Pythium and some Chytridiaceæ by E. J. BUTLER, M.B., F.L.S. Price, Rs. 4-8.

Vol. I, No. VI. Cephaleuros virescens, Kunze; The Red Rust of Tea by HAROLD H. MANN, D.Sc.; and C. M. HUTCHINSON, B.A. Price, Rs. 4.

Vol. II, No. I. Some Diseases of Cereals caused by Sclerospora Graminicola by E. J. BUTLER, M.B., F.L.S. Price, Re. 1-8.

Vol. II, No. II. The Indian Cottons by G. A. GAMMIE, F.L.S. Price, Rs. 7-8.

Vol. II, No. III. Note on a Toxic Substance excreted by the Roots of Plants by F. FLETCHER, M.A., B.Sc. Price, Re. 1-8.

Vol. II, No. IV. The Haustorium of Olax Scandens by C. A. BARBER, M.A., F.L.S. Price, Rs. 2-8.

Vol. II, No. V. The Haustorium of Cansjera Rheedii by C. A. BARBER, Sc.D., F.L.S. Price, Rs. 2-8.

Vol. II, No. VI. Some Experiments in the Hybridising of Indian Cottons by P. F. FYSON, B.A., F.L.S. Price, Re. 1-8.

Vol. II, No. VII. The Varietal Characters of Indian Wheats by ALBERT HOWARD, M.A., F.L.S., and GABRIELLE L. C. HOWARD, M.A. Price, Re. 1.

Vol. II, No. VIII. The Mulberry Disease caused by Coryneum Mori Nom in Kashmir, with notes on other Mulberry Diseases by E. J. BUTLER, M.B., F.L.S. Price, Re. 1-8.

Vol. II, No. IX. The Wilt Disease of Pigeon-Pea and the Parasitism of Neocosmospora Vasinfecta Smith by E. J. Butler, M.B., F.L.S. Price, Rs. 3.

Vol. III, No. I. Studies in Indian Tobaccos, No. 1. The types of Nicotiana Rustica, L., Yellow Flowered Tobacco by ALBERT HOWARD, M.A., A.R.C.S., F.L.S.; and GABRIELLE L. C. HOWARD, M.A. Price, Rs. 4.

CHEMICAL SERIES.

Vol. I, No. I. The Composition of Indian Rain and Dew by J. WALTER LEATHER, Ph.D., F.C.S. Price, Re. 1.

Vol. I, No. II. The Composition of Oil Seeds by J. W. LEATHER, Ph.D., F.C.S. Price, Re. 1.

Vol. I, No. III. The Pot-Culture House at the Agricultural Research Institute, Pusa, by J. W. LEATHER, Ph.D., F.C.S. Price, Rs. 3.

Vol. I, No. IV. Experiments on the availability of Phosphates and Potash in Soils by J. W. LEATHER, Ph.D., F.C.S. Price, Re. 1-8.

Vol. I, No. V. Construction of Drain Gauges at Pusa by M. H. ARNOTT, M.INST.C.E., with a Preface by J. W. LEATHER, Ph.D., F.C.S. Price, Rs. 3.

Vol. I, No. VI. The Loss of Water from Soil during Dry Weather by J. WALTER LEATHER, Ph.D., F.I.C., F.C.S. Price, Rs. 2.

Vol. I, No. VII. The System Water, Calcium Carbonate, Carbonic Acid by J. WALTER LEATHER, Ph.D., F.I.C., F.C.S., and JATINDRA NATH SEN, M.A., F.C.S. Price, Re. 1.

Vol. I, No. VIII. Water Requirements of Crops in India by J. WALTER LEATHER, Ph.D., F.I.C., F.C.S. Price, Rs. 3.

Vol. I, No. IX. The Nature of the Colour of Black Cotton Soil by H. E. ANNETT, B.SC. (Lond.), F.C.S., M.S.E.A.C. Price, Re. 1.

ENTOMOLOGICAL SERIES.

Vol. I, No. I. The Bombay Locust by H. M. LEFROY, M.A., F.E.S., F.Z.S. Price, Rs. 2-8.

Vol. I, No. II. The more Important Insects injurious to Indian Agriculture by H. M. LEFROY, M.A., F.E.S., F.Z.S. Price, Rs. 3.

Vol. I, No. III. The Indian Surface Caterpillars of the Genus Agrotis by H. M. LEFROY, M.A., F.E.S., F.Z.S.; and C. C. GHOSH, B.A. Price, Re. 1-8.

Vol. I, No. IV. Individual and Seasonal Variations in Helopeltis Theivora, Waterhouse, with description of a new species of Helopeltis by HAROLD H. MANN, D.SC. Price, Re. 1.

Vol. I, No. V. The Coccidæ attacking the Tea Plant in India and Ceylon by E. E. GREEN, F.E.S.; and HAROLD H. MANN, D.SC. Price, Re. 1.

Vol. I, No. VI. The Mustard Sawfly by H. M. LEFROY, M.A., F.E.S., F.Z.S.; and C. C. GHOSH, B.A. Price, Re. 1.

Vol. II, No. I. The Rice Bug by H. M. LEFROY, M.A., F.E.S., F.Z.S. Price, Re. 1.

Vol. II, No. II. Remarks on Indian Scale Insects (Coccidæ) by E. E. GREEN, F.E.S., F.Z.S. Price, Re. 1-8.

Vol. II, No. III. The Red-Cotton Bug by H. M. LEFROY, M.A., F.E.S., F.Z.S. Price, Re. 1.

Vol. II, No. IV. The Castor Semi-Looper by H. M. LEFROY, M.A., F.E.S., F.Z.S. Price, Rs. 2.

Vol. II, No. V. The Tobacco Caterpillar by H. M. LEFROY, M.A., F.E.S., F.Z.S. Price, Re. 1-8.

Vol. II, No. VI. The Cotton Leaf-Roller by H. M. LEFROY, M.A., F.E.S., F.Z.S. Price, Re. 1-8.

Vol. II, No. VII. Notes on Indian Scale Insects (Coccidæ) by H. MAXWELL-LEFROY, M.A., F.E.S., F.Z.S. Price, Re. 1-8.

BULLETINS ISSUED BY THE AGRICULTURAL RESEARCH INSTITUTE, PUSA.

No. 1. Notes on Cotton in Behar in 1904 by H. M. LEFROY, M.A., F.E.S., F.Z.S., Imperial Entomologist.

No. 2. An Outbreak of Cotton Pests in the Punjab, 1905, by H. M. LEFROY, M.A., F.E.S., F.Z.S., Imperial Entomologist.

No. 3. The Extension of Jute Cultivation in India by R. S. FINLOW, B.SC., F.C.S., Jute Specialist to the Government of Eastern Bengal and Assam. Price, As. 12 or 1*s.* 6*d.* (*Out of print.*)

No. 4. First Report on the Fruit Experiments at Pusa by A. HOWARD, M.A. (Cantab.), A.R.C.S. (Lond.), F.C.S., F.L.S., Imperial Economic Botanist. Price, As. 6 or 6*d.*

No. 5. Report on trials of the South African Locust Fungus in India by Dr. E. J. BUTLER, M.B., F.L.S., Imperial Mycologist; and H. M. LEFROY, M.A., F.E.S., F.Z.S., Imperial Entomologist. Price, As. 3 or 3*d.*

No. 6. Ticks Infesting Domesticated Animals in India by C. WARBURTON, M.A., Zoologist to the Royal Agricultural Society of England. Price, As. 4 or 6*d.*

No. 7. A Preliminary Account of the Biting Flies of India by H. M. LEFROY, M.A., F.E.S., F.Z.S., Imperial Entomologist. Price, Re. 1 or 1*s.* 6*d.*

No. 8. Official and Recommended Methods for use in Chemical Laboratories of the Department of Agriculture in India by J. WALTER LEATHER, Ph.D., F.I.C., F.C.S., Imperial Agricultural Chemist. Price, As. 4 or 6*d.*

No. 9. Report on Cocoanut Palm Disease in Travancore by Dr. E. J. BUTLER, M.B., F.L.S., Imperial Mycologist. Price, As. 4 or 6*d.*

No. 10. Treatment and Observation of Crop Pests on the Pusa Farm by H. M. LEFROY, M.A., F.E.S., F.Z.S., Imperial Entomologist; and C. S. MISRA, B.A. Price, As. 6 or 7*d.*

No. 11. On Flax Dodder by A. HOWARD, M.A., A.R.C.S., F.C.S., F.L.S., Imperial Economic Botanist. Price, As. 4 or 6*d.*

No. 12. The Making and Care of Lawns in India by A. HOWARD, M.A., A.R.C.S., F.C.S., F.L.S., Imperial Economic Botanist. Price, As. 4 or 6*d.*

No. 13. Sugarcane at the Partabgarh Experiment Station by C. CLARK, F.I.C., Agricultural Chemist, United Provinces; and Khan Bahadur S. M. HADI, M.R.A.C., M.R.A.S., Assistant Director of Agriculture, United Provinces. Price, As. 4 or 6*d.*

No. 14. The Milling and Baking Qualities of Indian Wheats by ALBERT HOWARD, M.A. (Cantab.), A.R.C.S. (Lond.), F.C.S., F.L.S., Imperial Economic Botanist and GABRIELLE L. C. HOWARD, M.A., Associate and late Fellow of Newnham College, Cambridge. Price, As. 4 or 6*d.*

No. 15. Note on the Extension of Cultivation of Fibre Plants in India. Price, As. 6 or 8*d.*

TEXT BOOKS.

"Indian Insect Pests" by H. M. LEFROY, M.A., F.E.S., F.Z.S. Price, Re. 1.

"Indian Insect Life" by H. M. LEFROY, M.A., F.E.S., F.Z.S., and F. M. HOWLETT, B.A. 786 pp. Price, Rs. 20.